Refinement of the currently used moisture content based maturity determination procedure

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ABSTRACT
The present project aims to facilitate the interpretation of avocado fruit moisture content readings by determining whether fluctuations are induced by environmental conditions, phenological factors or procedural inaccuracies. The first year's study consisted of three parts, namely: a moisture content survey with early season 'Fuerte' fruit; modeling of 'Pinkerton' size/maturity information; and a late season 'Pinkerton' maturity survey. The results indicated that deviations are primarily caused by interactions between sampling and fruit set growth/maturation factors. It is our opinion that the current PPECB sampling and moisture content determination procedures are adequate. It is, however, important that the procedure be repeated at least five times prior to harvest (initially twice a month and later on a weekly basis). In the case of late season orchards, it is essential to continue with the moisture content analyses until the packing date is reached.

INTRODUCTION

The currently used moisture content based avocado maturity measurement procedure has been in use for a number of decades and has served the industry well. It has been adopted worldwide, albeit that the inverse value (dry mass content) is used. However, variability that confounds the interpretation of the results is observed from time to time. The current project aims to aid the interpretation of these fluctuations by determining whether they are induced by environmental conditions, phenological factors or procedural inaccuracies.

MATERIALS AND METHODS

The study consisted of three parts, namely a survey conducted with 'Fuerte' fruit at ZZ2; modeling of 'Pinkerton' results generated by Arthur Sippel's team during the early nineties and a survey conducted at the Mayo Pack House in the Schagen Valley with the 'Pinkerton' cultivar.

ZZ2 'Fuerte' survey

Thirty six 'Fuerte' orchards located on the Wagendrift farm in the Mooketsi area were sampled over a nine week period at the beginning of 2013. The moisture content of each sample was determined using the PPECB prescribed microwave procedure. The procedure was first compared with the individual fruit oven based method and an automated technique and found to be accurate.

Moisture content/date graphs were drawn and deviations from the linear trend compared with possible concomitant changes in environmental factors and orchard management practices. These included climate (temperature and rainfall), orchard location, soil type, irrigation cycle, fertiliser programme, tree age, rootstock and yield.

Arthur Sippel team's 'Pinkerton' fruit set observations

During the early nineties Arthur Sippel of the Agricultural Research Council's Institute for Tropical and Subtropical Crops recorded the fruit growth patterns and maturation rates of 'Pinkerton' sets on trees planted in three locations (Schagen, Heidelberg and Kiepersol) in Mpumalanga (Sippel *et al*., 1992, 1993, 1994, 1995; Sippel, Holmes *et al*., 1995). In this part of the study, the information contained in these publications was used for modeling purposes. An attempt was made to establish what effect fruit growth patterns and maturation rate trends have on the accuracy of fruit moisture content analyses.

Mayo Pack House 'Pinkerton' survey

The Mayo Pack House specialises in the export of very mature 'Pinkerton' fruit. In order to do this, it is essential that the maturation rates of all orchards be closely monitored over the season and that the fastest maturing orchards will be harvested first. During the 2013 season, the maturation rates of 19 orchards were followed. Five samples of each orchard were taken as from the second week of April to the second week of

June. On every date five fruit were sampled from each orchard. The mass of the individual fruit was taken and the moisture content individually determined.

RESULTS AND DISCUSSION

ZZ2 'Fuerte' survey

Certain orchards displayed a linear moisture content reduction pattern. An example of such an orchard is shown in Figure 1a where the moisture content reduced from around 84% at the end of January to about 79% at the beginning of March. The moisture content of a second group of orchards followed the same pattern during the first four weeks of the monitoring period (Figure 1b). However, during the last week of February the moisture content of these orchards dropped steeply from around 80-81% to around 78-79%, after which the moisture reduction rate again stabilised (Fig. 1b). A third group of orchards showed a moisture content reduction rate slowdown at the end of January, followed by an acceleration at the end of February (Fig. 1c). In certain cases the moisture content readings of these orchards increased for a short period during the middle of February (Fig. 1d).

None of the observed deviations correlated with any of the biotic or abiotic factors listed above. However, closer inspection of the data revealed that the four basic patterns were closely mimicked in later maturing orchards (Fig. 2a-d). Similar rates of moisture content decrease, stabilisation and temporary increases occurred approximately three weeks later in these orchards at more or less the same moisture content levels.

The above results infer that environmental and managerial factors could not have caused the observed moisture content deviations and that they are rather to be attributed to interactions between certain sampling and/or phenological factors (next section).

Arthur Sippel's 'Pinkerton' fruit set observations

The fruit growth rates of the Kiepersol fruit are shown in Figure 3a (1990/91 season) and in Figure 3b (1991/92 season). The fruit growth rates of the Schagen fruit as recorded during the 1990/91 season are shown in Figure 3c, while those of the Heidelberg fruit, as recorded during the 1991/92 season, are shown in Figure 3d. The maturation rates of the Kiepersol fruit, as recorded during the 1992/93 season, are shown in Figure 4a while those of the Heidelberg fruit are shown in Figure 4b.

In most cases, the later sets grew at a faster rate than the earlier sets. However, the fruit growth rates differed between locations and seasons. For instance, at Kiepersol, the later fruit sets were larger than the earlier sets by February 1991 while this was not the case during February 1992.

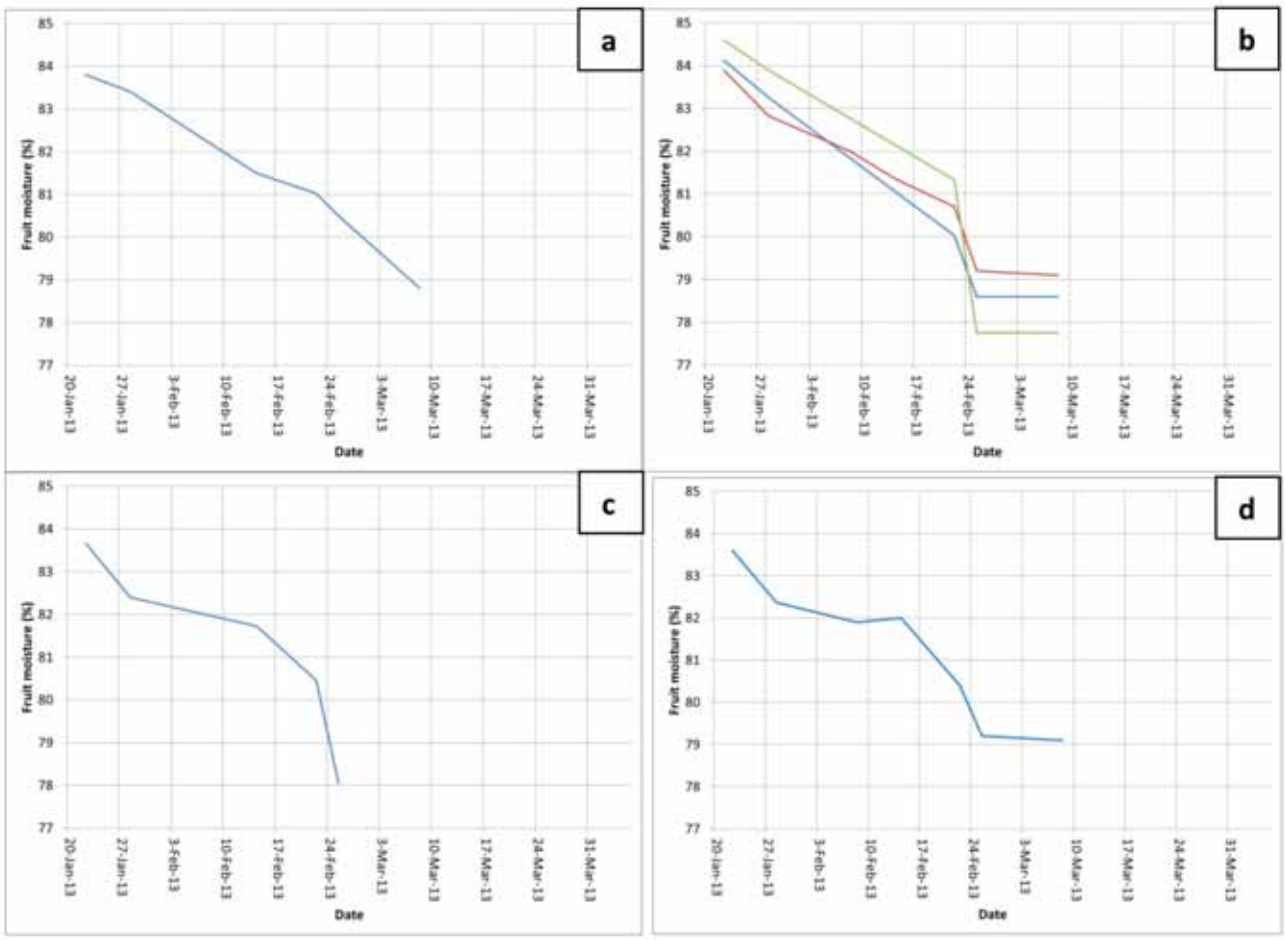

Figure 1. Four types of moisture content reduction patterns recorded in 36 'Fuerte' orchards at ZZ2.

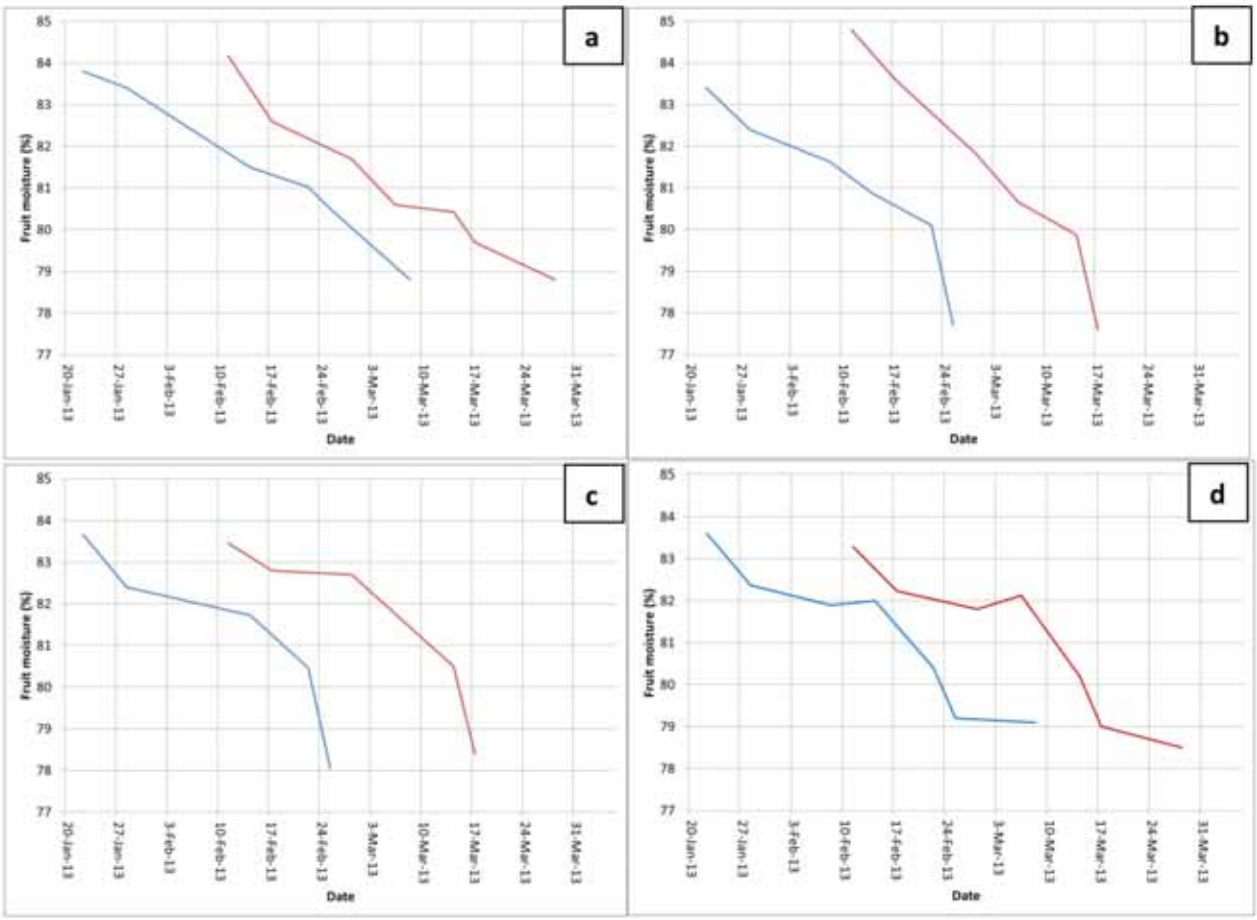

Figure 2. Recurrence of the four moisture content reduction patterns shown in Figure 1 in orchards that were approximately three weeks later than the first set of orchards.

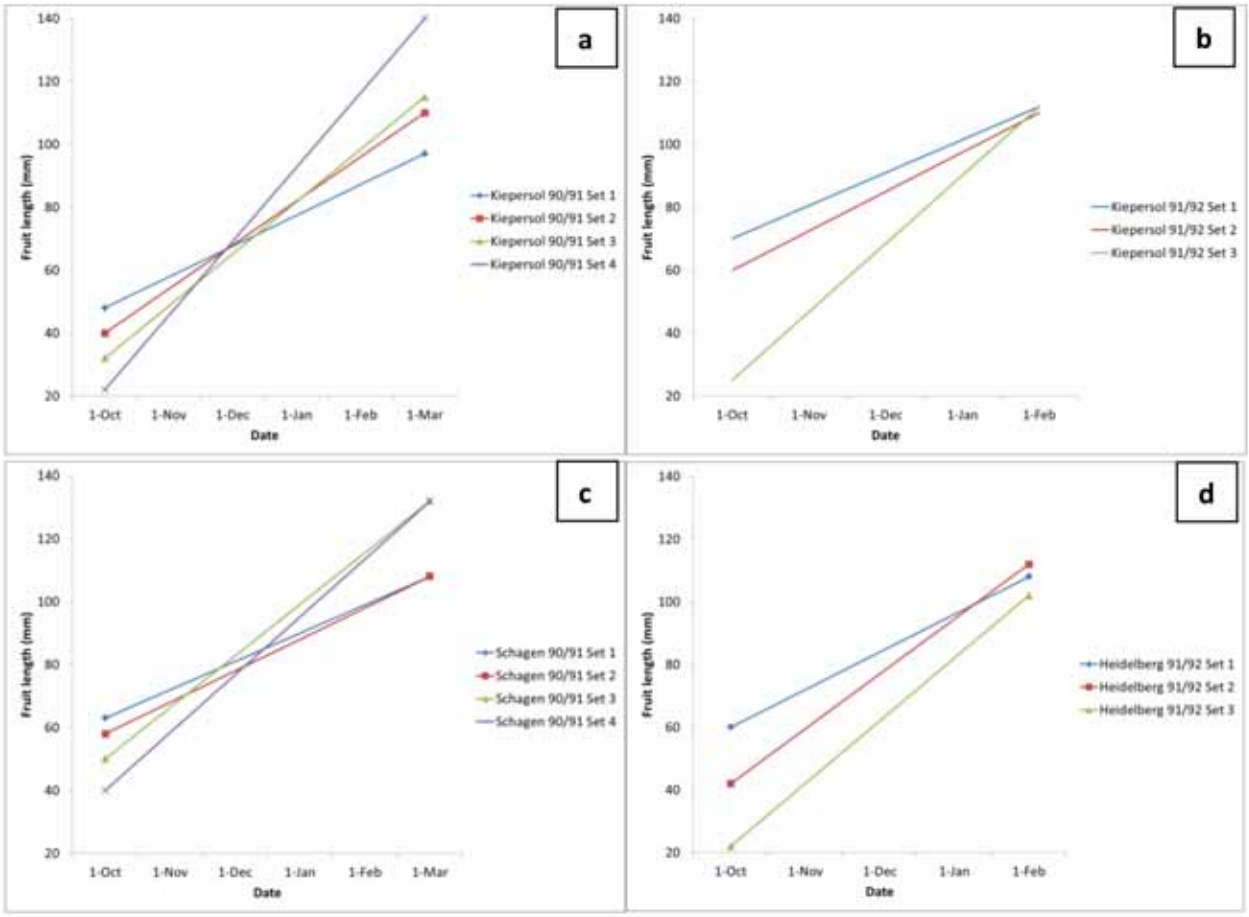

Figure 3. Fruit growth rates of 'Pinkerton' fruit at: (a) Kiepersol during the 1990/91 season; (b) Kiepersol during the 1991/92 season; (c) Schagen during the 1990/91 season; (d) Heidelberg during the 1991/92 season.

In contrast with fruit size, the maturation rates of the different sets decreased at more or less similar rates. Again, certain variations occurred. In the Kiepersol area (Fig. 4a) the above trend certainly applied. However, in the Heidelberg orchard the second set matured at a faster rate than the other two sets (Fig. 4b).

Examples of theoretical modeling based on the above information are shown in Figures 5a (Kiepersol) and 5b (Heidelberg). In both cases it was supposed that the person collecting the fruit for maturity analyses tended to sample fruit at the larger end of the size distribution range. Under these circumstances, the moisture content reduction rate of the Kiepersol fruit exhibited a concavely curved trend line quite similar to those recorded for some of the ZZ2 'Fuerte' orchards. In contrast, the moisture content of the Heidelberg fruit decreased in a convexly curved fashion.

The above results imply that moisture content deviations may be caused by growth versus maturation rate and sampling interactions.

'Pinkerton' survey at Mayo Pack House

The results of the moisture content analyses are plotted in Figure 8a. As may be deduced from the figure, the moisture content of certain orchards did not reduce in a straight line and a fair amount of variation occurred. Since this is a late season pack house and the 'worst case scenario' approach is followed, more mature values, recorded at an earlier date, take preference to less mature values recorded at a later date. A 'corrected' version of the graph, based on this principle, is shown in Figure 8b. (In case of early season pack houses a reverse strategy must be followed so as to ensure that the fruit are past the minimum maturity/maximum moisture level at harvest.)

This part of the study demonstrated that moisture content deviations can be resolved when a longitudinal data set is available.

RECOMMENDATIONS

It is our opinion that the current PPECB sampling and moisture content determination procedure is adequate for most scenarios.

- It is, however, important that the procedure be repeated at least five times per orchard prior to harvest (initially twice a month and later on a weekly

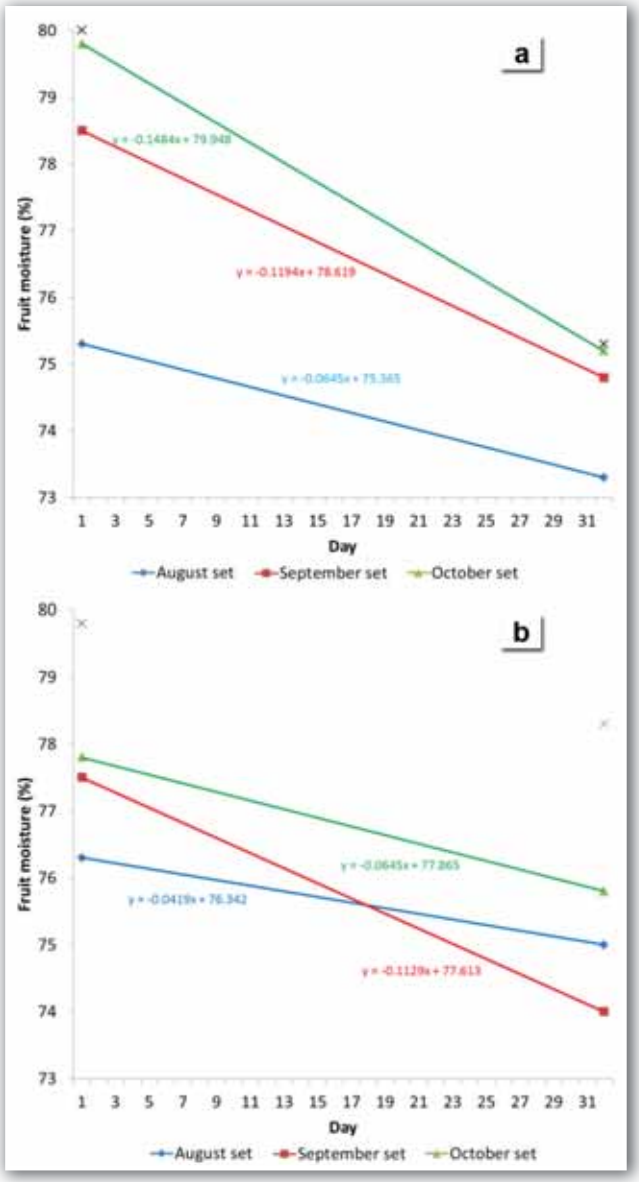

Figure 4. Maturation rates of 'Pinkerton' fruit as recorded during a 30 day period during the 1992/93 season at (a) Kiepersol and (b) Heidelberg.

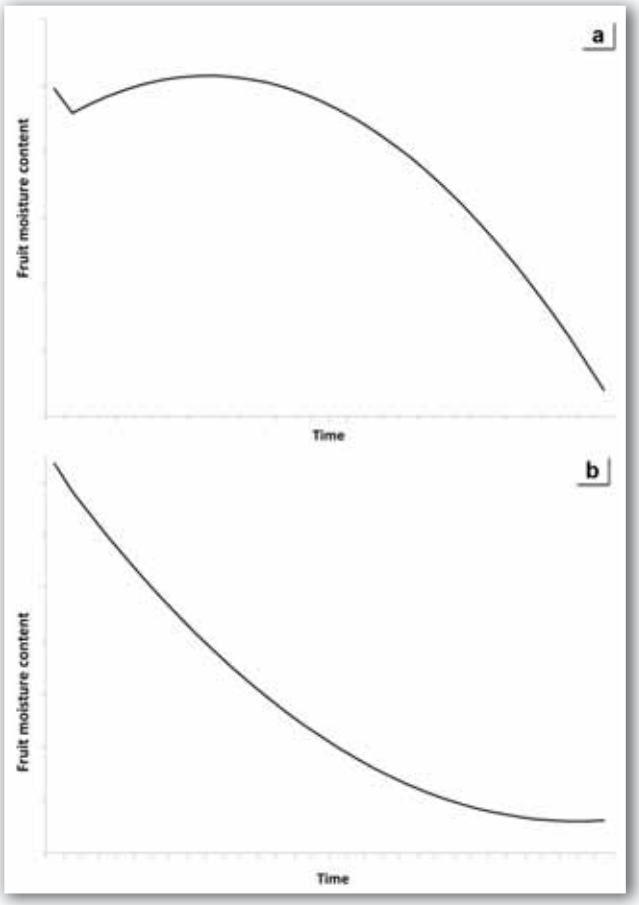

Figure 5. Examples of theoretical model based regressions founded on the information contained in Figures 3 and 4 for (a) Kiepersol and (b) Heidelberg.

basis). Additional samples must be taken should irreconcilable deviations occur prior to harvest.

- In the case of early season orchards, it is essential that ripening rate and taste tests also be performed.
- In the case of late season orchards, it is essential to continue with moisture content analyses up to picking.
- Certain scenarios may require special attention, e.g. when dealing with the 'Pinkerton' chilling injury issue, it may be necessary to perform moisture content analyses on individual fruit, rather than on the pooled samples. This must be done to determine what the maturity to size ratios of the different counts are.

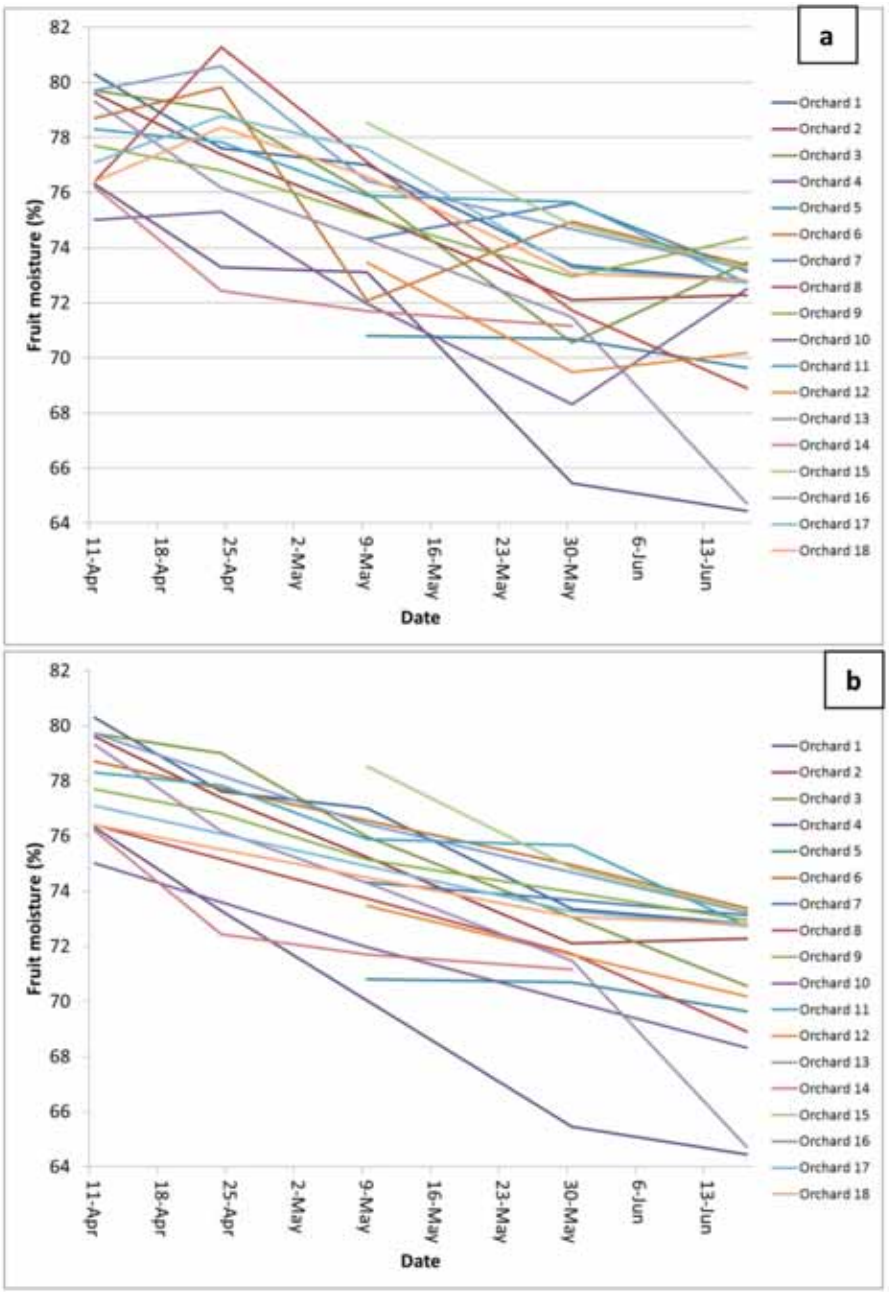

Figure 6. Moisture content reduction rates of 18 'Pinkerton' orchards in the Schagen Valley during the 2013 season: (a) full data set; (b) 'corrected' version.

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